Butternut (*Juglans cinerea* L.) Distribution for Estimating Butternut Canker Mortality Impacts and Potential Reintroduction of Resistant Trees

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Abstract

Butternut (*Juglans cinerea* L.), a widespread but rare tree, is being affected by a lethal canker disease caused by the *Sirococcus clavigignenti-juglandacearum* fungus. The fungus was probably introduced from outside North America and is possibly spread by insects. The first butternut deaths were reported in 1967 and butternuts of all ages are dying throughout the range of butternut in North America. Mortality from the fungus has resulted in the proposed listing of butternut as a threatened species in several states. We evaluated the distribution of live and dead butternut trees in the eastern United States using U.S. Forest Service Forest Inventory and Analysis (FIA) plot data. Butternut occurrence was then classified by ecoregion province and section levels. Significant differences in butternut occurrence existed at both levels. Across the east, 0.7% of FIA plots contained butternut while 2.1% of the plots in the Eastern Broadleaf Forest Continental Province (222) and 10.9% of the plots in the North Central U.S. Driftless and Escarpment Section (222L) contained butternut. Other sections with high occurrence included the St. Lawrence Valley Section (212E, 6.4%) and Hudson Valley Section (221B, 4.4%). Kriging was used to derive a probability map of butternut occurrence across the eastern United States. This map was then overlaid by forest density data, resulting in an adjusted probability map of butternut occurrence in eastern forests. Candidate areas for butternut reintroduction have been identified by this analysis.

Introduction

Butternut (*Juglans cinerea* L.) is a widespread, but rare tree. Its natural range extends from New Brunswick south to North Carolina, then west to Minnesota and south to Missouri. Additionally, small pockets of butternut occur in Arkansas, Alabama, Georgia, and South Carolina (Rink 1990) (Fig. 1). Butternut is valued for its wood, flavorful nuts, wildlife mast, and contribution to forest diversity. Its wood is used for furniture, paneling, specialty products, and carving.

Butternuts were first reported dying from a canker disease in 1967. Since then, butternuts of all ages have been dying throughout their range in North America (Ostry 1998b). The fungus *Sirococcus clavigignenti-juglandacearum* is the cause of the lethal stem disease that may be threatening the viability of butternut as a species (Ostry et al. 1994, Ostry 1998a, Nair 1998). This fungus was probably introduced into North America (Furnier et al. 1999) and is possibly spread by insects (Katovich and Ostry 1998).

Figure 1. Range of butternut (*Juglans cinerea* L.).

Objectives

➢ 1. To determine the frequency of occurrence of butternut using updated FIA data by ecoregions, states, counties, or other units.

➢ 2. To determine the site or stand factors in which butternut occurs to determine information for restoration and/or preservation.

➢ 3. To determine the change in butternut frequency over time due to incidence of butternut canker disease.

Methods

Only objective 1 will be addressed here.

➢ *Objective 1*

FIA plot data were classified according to occurrence of live and dead butternut trees. This analysis was done using the most recent periodic FIA data from each state in the eastwide database. The classified plots were further classified using a hierarchical ecological classification system of ecoregion provinces and sections (Bailey 1995, Fig. 2). A nonparametric data classification technique (CART) was used to look for differences in butternut occurrence between provinces and sections.

Ordinary kriging was used to estimate the probability of a cell having butternut present. These probability estimates were then adjusted for forest density using a land cover (proportion forest) map generated from Multi-Resolution Land Characteristics Consortium (MRLC) data. Each 30-m pixel was classified as either forest or non-forest and then pixels were aggregated into 1-km percent forest pixels. The forest density map values were then multiplied by the butternut probability map values to create an adjusted kriged butternut canker susceptibility map.

Figure 2. Ecoregion map of provinces (colored areas) and sections within provinces (black lines).

Ecoregion Provinces

Results

➢*Objective 1*

We first made a map of all FIA plots showing where any butternut tree was measured (Fig. 3). There is a strong correlation between the range map (Fig. 1) and butternut occurrence on FIA plots. We then grouped the FIA plots by province and section within the eastern United States and calculated the percentage of the FIA plots that had at least one butternut tree present. Seven of the 15 provinces contained no butternut. Butternut occurrence ranged from 0.01 to 2.09% of the FIA plots in the other 8 provinces (Table 1).

A Classification and Regression Trees (CART) analysis showed that the 15 eastern U.S. ecoregion provinces analyzed were classified to four significantly different groups based on the percentage of FIA plots containing butternut (Fig. 4). Another Classification and Regression Trees (CART) analysis showed that the 82 eastern U.S. ecoregion sections analyzed were classified into six significantly different groups based on the arcsin transformation of the proportion of FIA plots containing butternut (Fig. 5)[1]. Section 222L, the North Central U.S. Driftless and Escarpment, contained a significantly higher proportion of butternut (10.9%) than all other sections (Table 2). A map of ecoregion sections categorized by the CART analysis results highlights suitable butternut areas (Fig. 6).

Kriging produced a probability surface where the probability of butternut occurrence varied from 0 to 87.9 percent (Fig. 7). One problem with these kriged surfaces is that non-forested land is included in the surface. Using the forest density map as a filter, we could then adjust the probabilities to values that are more representative of actual forest occurrence. The resulting probability surface is reduced both in area (non-forest areas dropped) and in probability with the range now varying from 0 to 83 percent (Fig. 8).
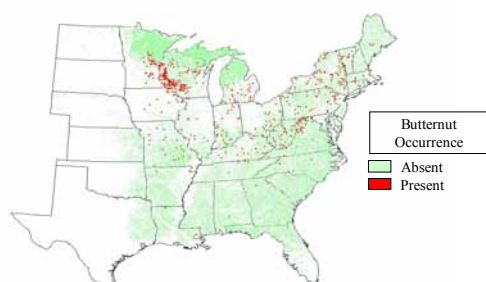
Figure 3. Presence or absence of butternut trees on FIA plots in the eastern United States. (Symbols for plots with butternut present are enlarged to aid viewing.)
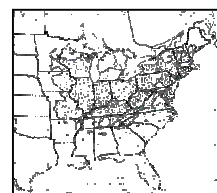
Butternut Occurrence
☐ Absent
☐ Present

Table 1. Butternut occurrence by ecoregion province.

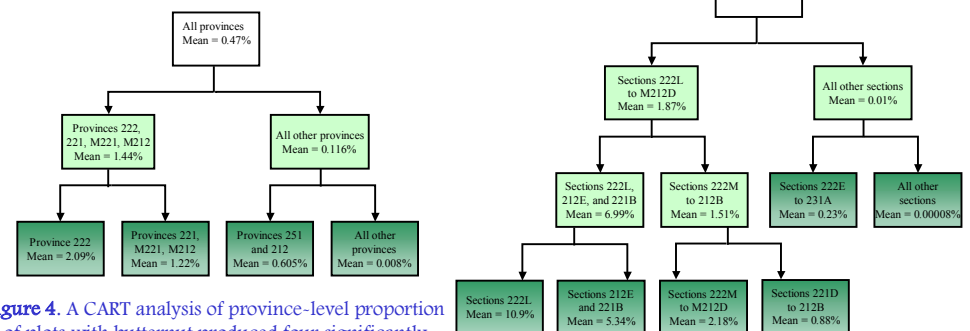| Province	# with Butternut	# of Plots	% with Butternut
222	290	13862	2.1
221	88	6318	1.39
M221	74	5614	1.32
M212	28	2915	0.96
251	26	4156	0.63
212	142	24321	0.58
231	8	14064	0.06
232	2	13659	0.01
234	0	1267	0.00
255	0	615	0.00
331	0	158	0.00
332	0	461	0.00
411	0	50	0.00
M222	0	474	0.00
M231	0	753	0.00

Figure 4. A CART analysis of province-level proportion of plots with butternut produced four significantly different groups.

All provinces Mean = 0.47%

Provinces 222, 221, M221, M212 Mean = 1.44%

All other provinces Mean = 0.116%

Province 222 Mean = 2.09%

Provinces 221, M221, M212 Mean = 1.22%

Provinces 251 and 212 Mean = 0.605%

All other provinces Mean = 0.008%

Table 2. Butternut occurrence by ecoregion section for the 20 sections with the most butternut.

Section	# with Butternut	# of Plots	% with Butternut
222L	132	1211	10.90
212E	14	219	6.39
221B	15	343	4.37
222M	46	1342	3.43
222H	15	514	2.92
222I	16	563	2.84
222J	28	1006	2.78
212F	32	1326	2.41
212K	33	1428	2.31
251B	5	226	2.21
M212C	10	484	2.07
221F	10	485	2.06
M221B	18	919	1.96
M221C	10	559	1.79
M221A	40	2387	1.68
251D	9	558	1.61
221E	39	2521	1.55
M212D	9	596	1.51
221D	3	209	1.44
221A	12	951	1.26

Figure 5. A CART analysis of section-level proportion of plots with butternut produced six significantly different groups.

All sections Mean = 0.34%

Sections 222L to M212D Mean = 1.87%

All other sections Mean = 0.01%

Sections 222L, 212E, and 221B Mean = 6.99%

Sections 222M to 212B Mean = 1.51%

Sections 222E to 231A Mean = 0.23%

All other sections Mean = 0.00008%

Sections 222L Mean = 10.9%

Sections 212E and 221B Mean = 5.34%

Sections 222M to M212D Mean = 2.18%

Sections 221D to 212B Mean = 0.88%

Figure 6. Map of ecoregion sections divided into categories by CART analysis.

Percent of Plots with Butternut
0.00008
0.23
0.88
2.18
5.34
10.9

Figure 7. Kriged map of butternut occurrence probabilities based on FIA plots for each ecoregion section.

Estimated Probability
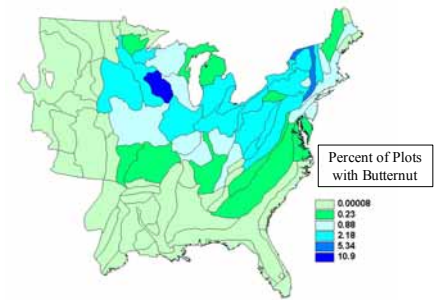0
0 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 0.9
No Data
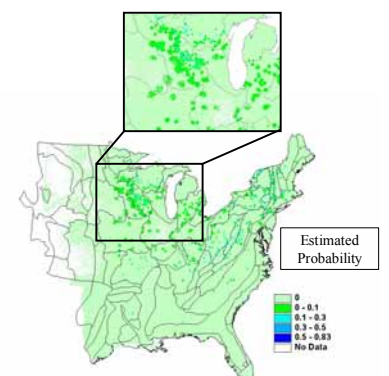
Figure 8. Kriged map of butternut occurrence probabilities adjusted for forest density.

Estimated Probability
0
0 - 0.1
0.1 - 0.3
0.3 - 0.5
0.5 - 0.83
No Data

Discussion

Comparing the results from the two techniques shows that both the ecoregional and plot kriging approaches have highlighted similar areas (i.e. the highest probabilities based on kriging are located in the sections with the highest occurrences). However, the kriged surface gives managers a better visual clue that not all of the area within a section is equally viable butternut habitat.

Butternut trees that are resistant to the canker disease have been identified (Fig 10). The results presented here highlight potential candidate areas for reintroduction of resistant butternut trees.

Our next step is to look at specific site characteristics of FIA plots that contain butternut and use CART and other classification techniques to separate out site characteristics that are associated with butternut habitat.

Figure 10. Healthy butternut reserve tree in an uncut control plot.

Conclusions

➢ Several provinces and a number of sections within provinces have significantly greater occurrence of butternut than others.

➢ Butternut occurrence, while rare, has a definite ecological relationship that can be used to identify areas for butternut reintroduction or preservation.

➢ Butternut regeneration will not be successful without resistant planting stock.

➢ Resistance appears to be persisting in some trees.

➢ Further analysis will look for site characteristics and mortality trends over time.

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